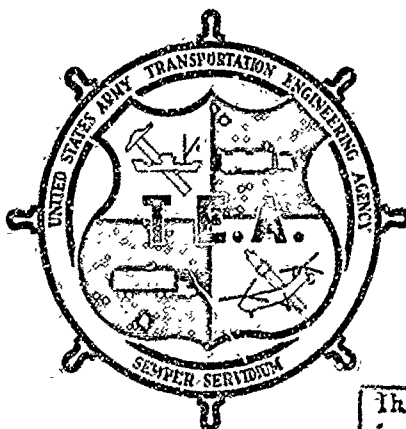TEA Report 64-11

DEPARTMENT OF THE ARMY
TRANSPORTABILITY CRITERIA
SHOCK & VIBRATION

by

Robert Kennedy

October 1964

U.S. ARMY
TRANSPORTATION ENGINEERING AGENCY
FORT EUSTIS, VIRGINIA

DEPARTMENT OF THE ARMY
TRANSPORTABILITY CRITERIA
SHOCK AND VIBRATION

Presented by

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U. S. Army Transportation Engineering Agency

Fort Eustis, Virginia

To the 34th Symposium on Shock and Vibration

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INTRODUCTION

Transportation-induced shock and vibration environments have been placed in an area of uncertainty for some time by both developers and users of equipment. Because of the variety of sources of accelerations and their many faceted appearances throughout the transportation system, efforts to handle these factors systematically have been impeded. In some areas, no transportability criteria exist. In other areas, there is no agreement on criteria. Incentives for compliance or utilization are missing. Understanding and compliance to criteria is not often a broad picture advantage to the complier.

Considerable efforts have been expended in collecting and analyzing oata and in testing components or systems for transportation shocks and vibrations. Technical knowledge has been gained as a result of these efforts. The flow of this knowledge from developer to manufacturer to purchaser probably has not been as great as most think necessary. The flow of information to the user or operator in these areas has been even more scant. By the time transportation items are in the system, the operator has a greater need for shock and vibration criteria than the developer. Certainly it is no asset for the operator to know that the fragility of his cargo is 5g. To give the operator information regarding speed reduction, cargo placement, or mode alternatives for a sensitive and priority cargo provides an opportunity for a great amount of good.

Organization and communication of criteria have been increasingly difficult tasks bec use of the fundamental changes in cargoes. A cargo that dictates cont erations of sensitivity, safety, or priority immediately triggers changes in the entire transportation system. Cargo has for the most part in the past accommodated itself to the carriers. As cargoes become more important, transportation systems have to accommodate for cargoes. In the area of shock and vibration, this accommodation is complex. The result must be a two-way street of accommodation.

The need for criteria is generated as the result of change. For rapid and broad communication of criteria, timely authenticated publications are necessary. Technical Bulletin 55-100, "Transportation Criteria - Shock and Vibration", was prepared and published to state the Department of Army interim position regarding shock and vibration. With this start, we hope to speed up the task of sifting, analyzing, checking, and communicating transportation shock and vibration criteria.

DISCUSSION

GENERAL

Many factors--some definite and particular, some intangible--were em-
ployed to determine the transportability criteria set forth in TB 55-100.
In the stiff process of setting down these factors for review, it becomes
apparent that criteria factors of greatest depth, subtleness, and scientific
origin provide the points which can be subs antiated and warranted most
readily. It is thought that good criteria must be provable and perhaps
even saleable to large numbers of personnel of differing backgrounds. The
following approach was chosen to accommodate a broad range of audience.

In regard to cargo, transportation-induced shocks start from a change in
velocity of the cargo. Although obvious, it should be noted that, except
for handling, the cargo only need change velocity so it can accommodate
its carrier. The carriers change velocity for many reasons that are
organic to their operation. In the process of keeping the cargo with the
carrier during various velocity changes of the carrier, abrupt or gentle,
a necessary force system results to maintain equilibrium conditions. To
restrain cargo and to design cargo with adequate hardware, it is necessary
first to reduce the forces by proper cushioning, as much as economically
feasible; then with proper structural design, provide adequate hardware.
These two factors interact to make the selection of quantitative amounts of
cushioning and structural materials
dependent on a host of other con-
siderations. Cost and reliability
are perhaps the major ones, fol-
lowed closely by operation, size,
and weight.
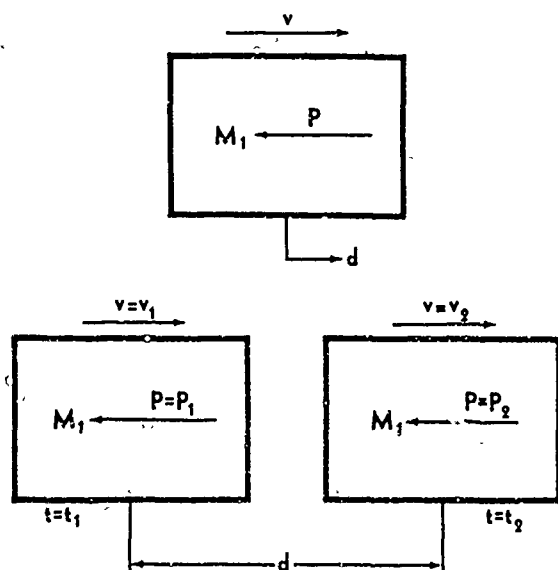
Consider the top sketch in Figure 1,
where M is a general mass of
cargo; v is the velocity of the cargo
at any time; and the vector force,
P, is the external force or the
inertia force resulting from the
change in velocity of the mass.
The distance direction is denoted
as d. The lower portion of Figure
1 sets up a specific happening
where the velocity changes from v_1
to v_2 in any general fashion as
shown in Figure 2. The velocity

Figure 1. Free Body Diagram.

2

change occurs during the time span, t, between t_1 and t_2. The external force or inertial force is shown, in the lower portion of Figure 2, as changing in any manner from P_1 to P_2 during the time interval. It can be seen that the primary object is to effect the change in velocity from v_1 to v_2, which is consequent to the change in velocity in the carrier, with a minimum P force or acceleration.
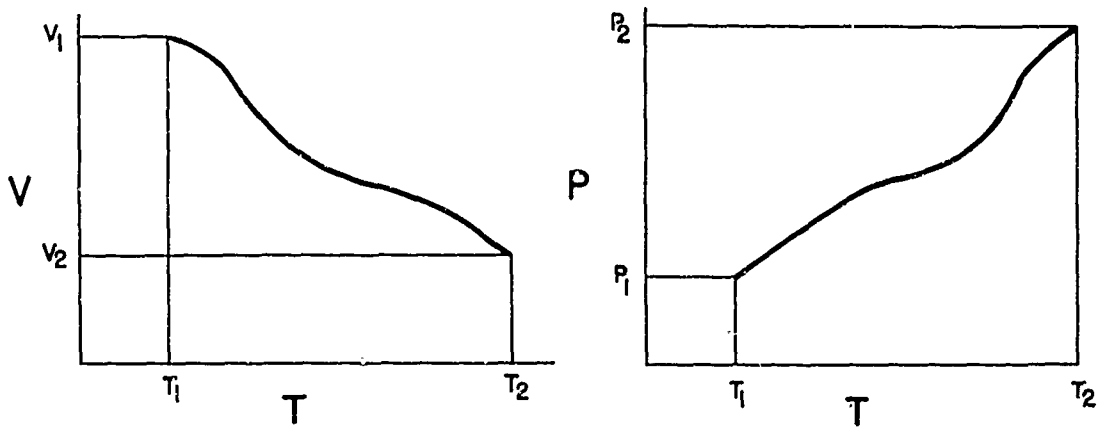
Figure 2. Velocity and Force Time Plots.

The total energy in the system at the start of the time interval t_1 is the kinetic energy of the mass, or

$$E_{t_1} = \frac{Mv_1^2}{2}. \tag{1}$$

The energy of the system at the time interval t_2 is the kinetic energy, or

$$E_{t_2} = \frac{Mv_2^2}{2}. \tag{2}$$

During the time interval, the change in energy, $\triangle E$, resulting from velocity change is the difference between the energy at t_1 and the energy at t_2, or

$$\triangle E = E_{t_1} - E_{t_2} = \frac{M}{2}(v_1^2 - v_2^2). \tag{3}$$

For the example set up, this much of the mechanical relationships is fixed as regards the cargo. The vehicle has changed its velocity, and the cargo must change its velocity also to remain with the vehicle. During this

3

process, a definite amount of energy, as shown in Eq. (3), must be expended on the cargo to effect the velocity change.
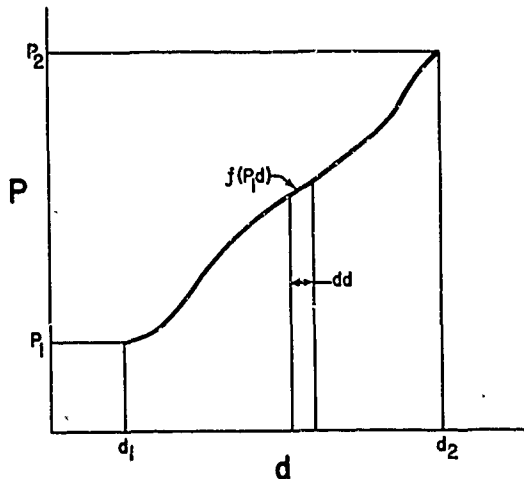

Figure 3. General Force Travel Curve.

The force, or acceleration, occurs over a distance span as shown in Figure 3. If the cargo is secured rigidly to the carrier, then the distance is whatever distance the main cushions of the carrier allow during the velocity change, as the carrier and cargo are the same mass. Most fragile cargoes have their own cushioning, which responds usually at a time after the velocity change has been effected in the carrier. When this happens, the cargo cushions are substantially mechanically independent of the main cushioning elements. This out-of-phase shock relationship occurs frequently with long shock-pulse-duration accelerations.

The change in energy is the product of the force times the travel, P· d, and can be expressed for Figure 3 as follows:

$$\triangle E = P \cdot d = \int f\,(P, d)\ dd.$$ (4)

It can be seen that there are many possibilities of effecting the force and travel to arrive at the same energy change $\triangle$ E. Several of the more common springs or cushions will be evaluated to assign quantitative numbers to the variations.

The example chosen is a substantially rigid cargo weighing 100 pounds. The item need be decelerated from 10 feet per second to 2 feet per second; the cushioning in the carrier functioned at a time before the mass responded. Substituting these values in Eq. (3), the change in energy would be

$$\triangle E = \frac{M}{2} (v_1^2 - v_2^2) = \frac{100}{32.2x2} (100-4)$$ (5)

$$= 149\ \text{ft-lb.}$$

4

For the first example, assume the item was decelerated in a distance of 3 inches (.25 ft) with a linear spring. Most practical cushioning devices employ a precompression as a simple method of getting more energy absorption for a given travel. Ten percent precompression is assumed throughout to establish practical examples. The curve shown in Figure 4 illustrates the characteristics. From Eq. (4),

$$\int f(P, d)\, dd = \int_{d_1 = 0}^{d_2 = 1/4} (P_1 + kd)\, dd \tag{6}$$

$$= P_1 d + \frac{kd^2}{2} \Bigg|_{d = 0}^{d = 1/4} = \frac{P_1}{4} + \frac{K}{32} = \frac{11}{80} P_2.$$

$$P = P_1 + kd \qquad K = \frac{18}{5} P_2 \text{ for } d_2 = .25'$$

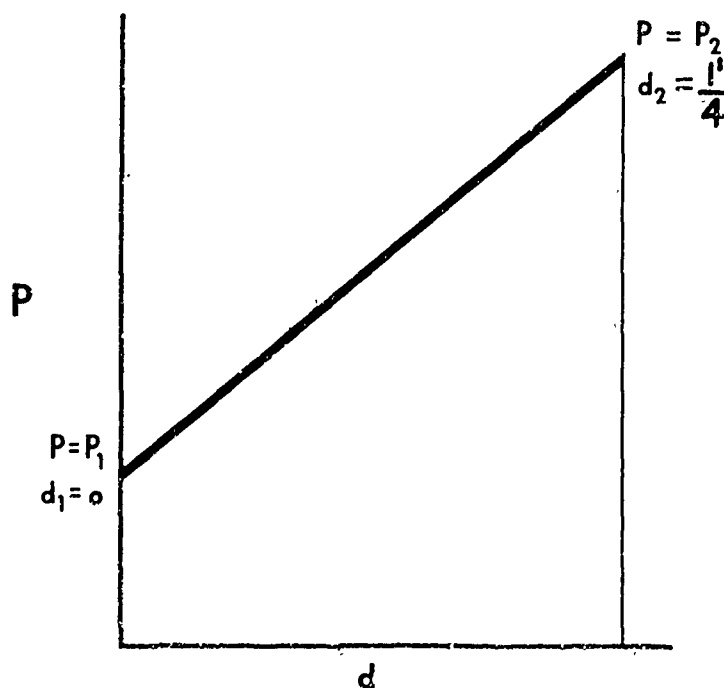$$P_1 = \frac{P_2}{10} \qquad K = \frac{9}{5} P_2 \text{ for } d_2 = .50'$$

Figure 4. Force Travel Curve for Linear Spring.

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From Eq. (4),

$$\triangle E = P \cdot d \qquad (4)$$

$$149 = \frac{11}{80} P_2$$

$$P_2 = 1,075 \text{ lb, or } 10.7g.$$

For the same spring characteristics and twice the travel (.50 ft), the force P_2 would be

$$\triangle E = \int f(P, d) \, dd = \frac{P_2}{20} + \frac{9}{2}(1/4)(1/2) P_2 \qquad (7)$$

$$P_2 = 537.5 \text{ lb, or } 5.4g.$$

It should be pointed out that extending the travel involves more than a simple increase in the clearance. It requires that springs, slides, fittings, and spring containers be twice the length. Spring instability problems as well as nonavailable space or increase in mass all make a fairly obvious improvement to reduce the force oftentimes impractical.

Next consider the exact same input using a cushioning device with a force travel curve shaped as a cubic parabola, as shown in Figure 5. For direct comparison, a 3-inch travel and a 10-percent precompression are assumed. These characteristics are similar to those of rubber in compression with very low unit pressures.

Evaluating the integral from Eq. (4),

$$\int f(P, d) \, dd = \int_{d=0}^{d=d_2} \left(\frac{P_2}{10} + \frac{288}{5} P_2 d^3 \right) dd \qquad (8)$$

$$= \left. \frac{P_2 d}{10} + \frac{288}{5} \frac{P_2 d^4}{4} \right|_{d=0}^{d=1/4}$$

$$= \frac{13}{160} P_2.$$

6

P = P_2

$d = \frac{1'}{4}$

P

$P = P_1$

$d = 0$

d

$P = P_1 + kd^3$

$P_1 = \frac{P_2}{10}$

$K = \frac{288}{5} P_2$
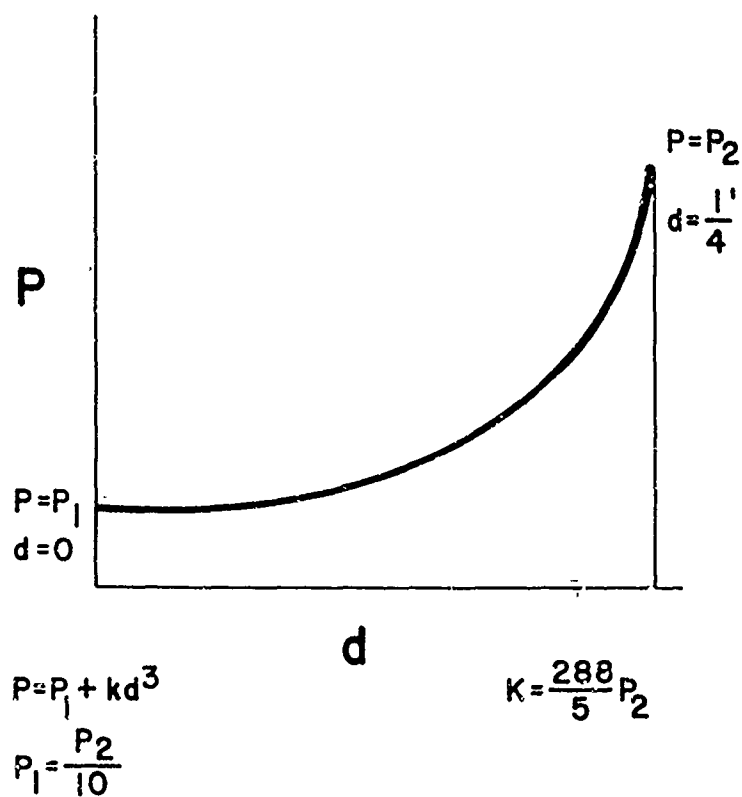
Figure 5. Force Travel Curve for Spring,
Cubic Parabola.

Substituting the area in Eq. (4),

$$\triangle E = 149 = \frac{13}{160} P_2. \tag{9}$$

Solving for P_2,

$$P_2 = 1,830 \text{ lb, or } 18.3\text{g}. \tag{10}$$

Using the same procedure with a squared parabola, Figure 6, which approximates rubber in compression with an even lower unit pressure, the maximum force is

$$P_2 = 1,490 \text{ lb, or } 14.9\text{g}. \tag{11}$$

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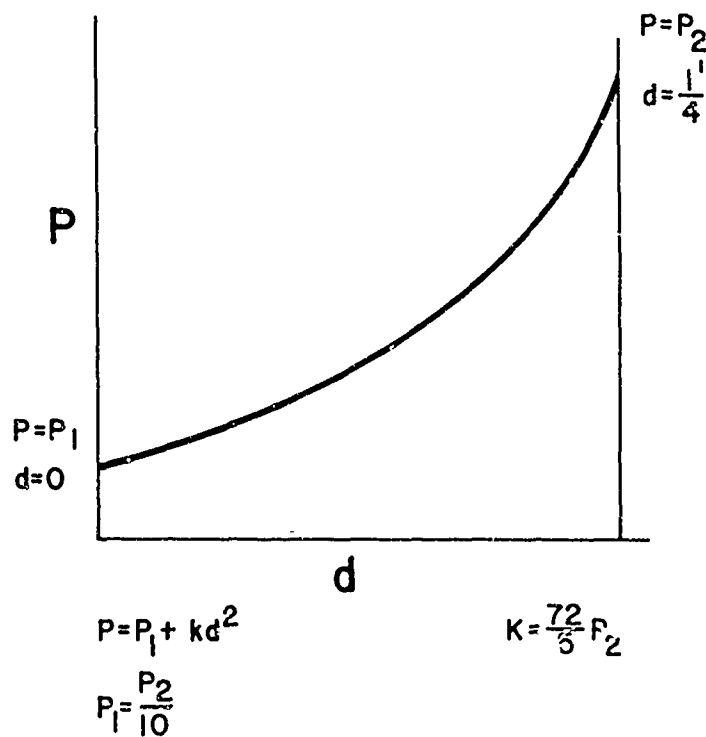
Figure 6. Force Travel Curve for Spring, Parabola.

To complete the comparison, performance will be calculated for a cushioning unit with an ideal curve, Figure 7. Hydraulic units, either separately or in combination with other units, come closest to this curve shape. This curve shape will approach the upper parameter for the assumed set of conditions.

From Eq. (4),

$$\int f (P, d)\, dd = P \cdot d = \frac{P_2}{4} \tag{12}$$

$$\triangle E = 149 = \frac{P_2}{4}$$

$$P_2 = 596 \text{ lb, or } 6g.$$

8

$P = P_2$

$d = \frac{1}{4}$

P

d

Figure 7. Force Travel Curve for
Ideal Spring.

Figure 8 illustrates that, when all conditions are kept the same and the travel is doubled, the damaging force on the cargo is halved. It shows immediately how dependent the environment (in terms of acceleration and pulse time) is on the makeup of the mechanical system.

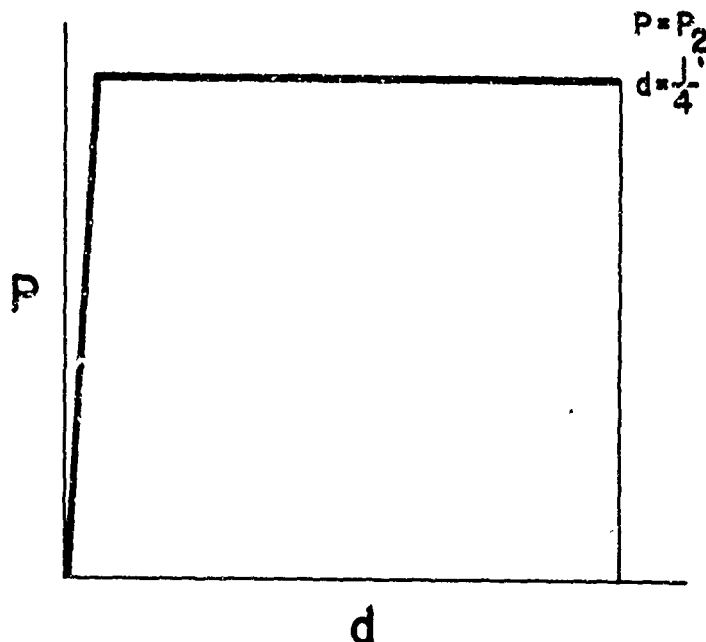With even the travel remaining constant, significant changes occur. Figure 9 shows that the peak damaging force can vary from 6g to 18g as a result of changes in the cushion curve shape. Only long travel cushions giving reasonably good performance were illustrated. With poor cushioning, the damaging force could easily go to 40g. Where great gains can be made in the high-frequency range with relatively little hardware, it is pointed out that much hardware is required in the low-frequency range and the resultant gains are not nearly so

MAX DECELERATION FORCE
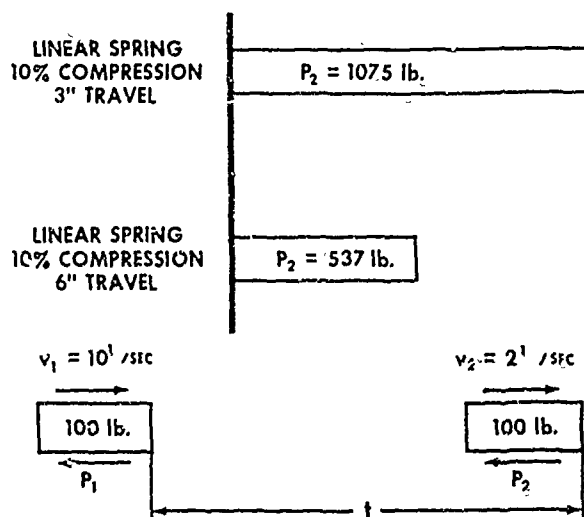

LINEAR SPRING
10% COMPRESSION
3" TRAVEL

$P_2 = 107.5$ lb.

LINEAR SPRING
10% COMPRESSION
6" TRAVEL

$P_2 = 53.7$ lb.

$v_1 = 10^1$ /sec

$v_2 = 2^1$ /sec

100 lb.

P_1

100 lb.

P_2

t

Figure 8. Comparison Cushion
Force Versus Travel.

9

MAX DECELERATION FORCE

LINEAR SPRING
10% PRECOMPRESSION
$P_1 = 1075$ lb.

PARABOLA SPRING
10% PRECOMPRESSION
$P_2 = 1490$ lb.

CUBIC PARABOLA SPRING
10% PRECOMPRESSION
$P_2 = 1830$ lb.

IDEAL SPRING
VELOCITY SENSITIVE
$P_2 = 596$ lb.

10'/sec   2'/sec
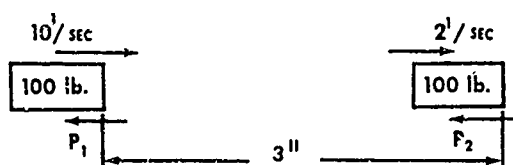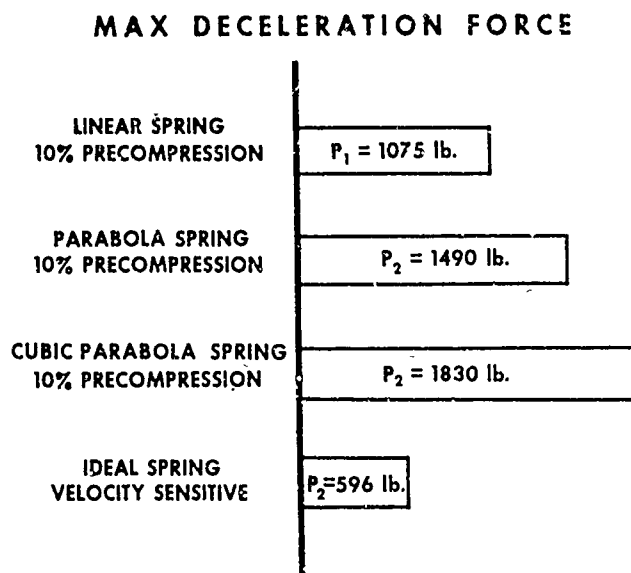
100 lb.   100 lb.

P_1 3" P_2

Figure 9.   Comparison Cushion Force
Versus Curve Shape.

dramatic. For the problem illustrated, going from 10.7g with a linear spring to 6g with an ideal spring combination involves considerable hardware, space, weight, and maintenance as well as considerable engineering and design efforts. An aircraft landing gear is perhaps the best example of the severe price paid to keep the accelerations tolerable. Cargoes cannot afford the extraordinary attention demanded by aircraft components.

Transportation-induced vibrations to cargo have some considerations that pertain equally well to transportation shock. However, several basic differences set the control of vibration apart from the control of shock, though they are both accelerations. For example, in the case of transportation shocks, the vehicle is accelerated, rather than the cargo which is moving to stay with the vehicle. Figure 10 is a schematic of cargo being transported on a carrier. The external force P is impressed upon the carrier which, in turn, transmits a vibration thru cushioning elements to the cargo. As shown in the diagram, these vibrations for sophisticated cargo are usually transmitted thru a spring and/or a dashpot intended to reduce the effects of the environment.

Since the velocity of vibrations is oscillatory, it is possible, through design, to eliminate most or all of the vibration. The mass can stay relatively motionless while the carrier is vibrating because there is no resultant absolute velocity. For shocks, the velocity change is usually absolute; the result of a start or stop. For vibrations, the conditions are the same after several cycles with no absolute motion resulting.

For vibrations in the low-frequency range, the resultant forces can be controlled; but, as it was for shock, the efforts required are great and
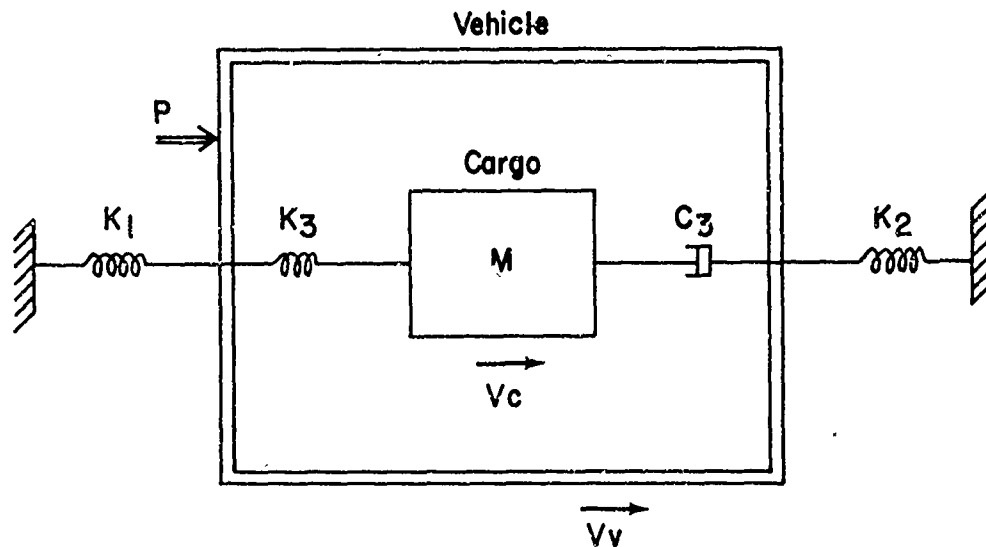
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Figure 10. Vibration Diagram.

the results obtained are conservative. It should be pointed out, however,
that the majority of reported damage experienced by Army cargoes are
attributable to the low-frequency shocks and low-frequency vibrations.
Another area requiring emphasis is high-frequency response to mechani-
cal system components initiated by low-frequency inputs. Consequent
damage to the cargo can oftentimes be eliminated by adjustment to the
low-frequency input. Much effort needs to be put forth in the low-
frequency shock and vibration as regards transportation environments be-
cause great practical gains need be made in this area.

For transportation vibration, the damaging forces can be controlled.
Setting environments in terms of amplitudes and frequencies does not
establish a specific base. The attachment of the cargo to the carrier and
the carrier itself can be easily changed to improve or worsen the vibra-
tion over what has been recorded and analyzed.

Beyond the mechanical considerations, the next major consideration is the
problem of ruggedness and cushioning. A persistent question always is
whether to make a cargo structurally stronger to withstand the transporta-
tion environment or to leave it as it is and cushion to obtain low force
levels. As with the problem of chicken eggs, obviously one can't tell the
hens to lay stronger eggs, so the cushioning must be such to reduce the
force level to a tolerable amount. For some items, it was found that the
small damage resulting from improper cushioning is not worth the cost of
proper cushioning. The latter case is quite rare and usually involves bulk
cargoes or ones of low value.

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A Transportation Corps in-house problem in regard to cushioning versus ruggedness involves shock and vibration instrumentation. Many shock and vibration requirements must be met in designing the equipment to withstand the transportation environment. Concessions are required by the instrument people who have secondary interest in transportation environment but are dedicated to improving the electromechanical properties of the instrument. Considerable interest was shown at first in making rugged instruments that would withstand any transportation-induced load; however, cost, design, and performance compromises have since dulled this interest.

The Transportation Corps is currently studying hardware that will attenuate low-frequency shocks and vibrations by long travel springs. Initial study work is promising; but these devices take space, cost money, and add weight. Every cargo has these same factors to be evaluated when control of shock and vibration is attempted. It is becoming painfully apparent that ruggedness in design to withstand transportation environments must be accomplished in addition to adequate cushion design. These two factors must be studied thoroughly and specifically for individual items. Success is usually achieved by applying improvements to both factors. Other factors, such as priority and reliability, must be weighed and integrated into the system design. Proper application of all factors is needed to produce the most effective and efficient item complete with its transportation requirements. Each factor should be evaluated in conjunction with, but preferably not by, the manufacturer of the cargo or the manufacturer of the transportation equipment. For commercial products, the shipper is probably the most logical study agent. For military cargoes, the military themselves, either direct or thru contract, are the preferred responsible study group. For the Army, the Chief of Transportation conducts this type analysis work, especially as regards combinations of scientific, engineering, cost, and military connotations.

The Department of Army's approach regarding transportation-induced shocks and vibrations has been to deal with numbers and conditions that cannot be altered by cusioning. As was pointed out by the previous discussion, with unlimited weight, money, and size for cushioning, the damaging effects of transportation-induced shocks and vibrations can be virtually eliminated. The Transportation Corps' position is to establish such factors as rail impact velocity, landing rate, road condition, and sea state. With such factors, cushioning can be properly evaluated as to its worth for economic and reliable transportation as well as its efficiency and effectiveness within the framework of the transportation system.

To list criteria for cargoes in terms of acceleration and frequencies is not consistent with the present state of engineering as regards shock and

vibration. It sets an arbitrary level of performance and makes no provision for rewarding improvement on the preset performance level. To say "Design and restrain for 8g in railroad operation" does not lead to more effective transportation. Recent developments have shown that items with a fragility level of 2g have been transported by rail at low cost, with low damage, and timely transit.

Sensitive and sophisticated military cargoes are prime examples of items that should not be penalized as regards transportation or modes of transportation. The face value fragility of the item compared with the face value shock and vibration environment of the carrier seldom gives the answer of how best to transport an item. If it is important that particular items be transported efficiently and effectively, then it is doubly important that an intelligent and scientific look be given to all criteria factors to insure that the best transportability is being afforded.

Army Technical Bulletin 55-100, "Transportability Criteria - Shock and Vibration", was published in April 1964. Of interest here is the manner in which the shock and vibration criteria were set forth. For all modes, the criteria were given first in terms of the relatively unchangeable conditions that are, in fact, transportation-induced shock and vibration inputs. For example, the criteria were given for a rail impact velocity of 8 mph and 10 mph. This factor is a consequence of rail operation, and cushioning engineering and design must accommodate to meet the criteria. The resulting accelerations and vibrations to the cargo can be almost anything, depending on how much cushioning is warranted. To say an item is transportable by rail, means that the hardware designs to get the shocks below the fragility level are consistent with cost, weight, and size.

Figure 11 is a copy of the first page of TB 55-100; Figures 12, 13, 14, and 15 are taken from the TB. For each mode of transportation, the readings represent the maximum shock accelerations and vibrations found to date as a result of instrumented movements and tests. It is seen that these data are quite high as regards amplitude. Many items would be penalized unnecessarily if only the plotted data were considered.

The intended approach for use of the TB is contained in a twofold consideration: (1) If an item has sufficient strength to withstand the plotted data from the figures applied, as in the text of the TB, it will withstand the maximum environment determined to date; and (2) if, for any number of reasons, the item or its restraining system cannot meet the plotted data, the item must then be evaluated in conjunction with such basic inputs as road conditions or sea states. This approach is intended to separate the items meriting special attention from those rugged enough not to need special attention.

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Besides Transportation Corps-initiated studies, several hundred other works by Government agencies, research institutions, and industries were utilized to devolve transportability criteria. It should be pointed out here that all organizations cooperated fully in making the data available. Many of the tests conducted by these organizations were for purposes other than measuring shock and vibration environment. In many instances the Transportation Corps was able, with little additional effort or cost, to augment the base program to obtain environmental data.

All criteria in the TB have some backup. The rail impact speed of 10 mph is one that Transportation Corps cargoes have experienced. Sea state 12, landing rate 10 feet per second, and paved roads of PSI index 1 are all occurrences which cargoes have experienced and which have been recorded. The number and duration of the experiences require further input for confidence as to accuracy. For this reason, throughout the TB, recommendation for increase in shock numbers or time of vibration has been suggested for safety factors. Much more is known about amplitudes than about durations or frequency of occurrence; thus one needs a greater reason for changing amplitudes.

The data in curve form (Figures 12-15) represent an envelope of the maximum data recorded. Many of the points were from cargoes that were mounted on their own suspension units, which may have responded to amplify the input. Other data used may possibly be lowered by minor design changes. All reasonable and substantiated data were included to make up the curves.

TB 55–100

DEPARTMENT OF THE ARMY TECHNICAL BULLETIN

TRANSPORTABILITY CRITERIA
SHOCK AND VIBRATION

Headquarters, Department of the Army, Washington, D.C.
17 April 1964

1. **Purpose.** This bulletin sets forth the Department of the Army interim position as regards engineering considerations of shock and vibration environments induced by transportation. It also furnishes basic transportation engineering design parameters for research and development design usage in conjunction with transportability of military items.

2. **Scope.** The information contained in this bulletin is applicable to all Army cargoes and in particular for rail, air, sea, and highway modes of transport. Shocks and vibrations are illustrated as envelopes of data that inclose maximum accelerations

3. **General.** a. Increased use of fragile, sensitive, and dangerous items and increased importance of such military items have established an urgent requirement for formal guidance as regards transportation environments. The increasing variety of both military cargoes and transport vehicles with their differing size, mass, and internal cushioning has complicated the process of establishing specific guidelines useable for a broad range of items and carriers.

b. Certain data can be established now in the field of transportation shock and vibration that will be extremely helpful for technical communications and as a tool for analytical comparison. The first step is to obtain and use acceleration inputs to a transportation system that are independent of the operational characteristics, such as the physical state of the right of way, impact speed, sea state, and landing rate. From this point, other factors can be presented that are determined wholly or in part by the mechanical makeup and operational characteristics of the transportation system, and that are peculiar to the specific system.

c. It is recognized that some combination of forces, accelerations, and frequencies that would classify and standardize the required strength of a broad range of cargoes would be a most useful tool. Work to date in this area has been accomplished on selected items. A complete scientific methodology requires a broad background of field studies designed specifically for this purpose. Considerable effort has been expended, and enough studies have been conducted to develop, empirically, certain shock and vibration producing factors. These factors are illustrated and published here to initiate a better interchange and comparison of transportation shock and vibration data; also, to increase utilization of existing data in initially establishing a methodology stated in mathematical and mechanical terminology

d. The data and guidelines contained in this bulletin comprise the Department of the Army, Chief of Transportation interim position. Transportation Corps efforts will be continuous to keep up with technological advances; the basic factors will be adjusted as required, and additional findings will be included to extend toward the development of a definite analysis procedure.

4. **Rail.** a. The cargo and its restraining systems should be capable of withstanding a transportation shock environment simulated by three successive rail impacts in both car directions of 10-mile-per-hour seventy for priority, high value, and sensitive cargoes and 8 miles per hour for general troop support cargoes. The striking (or the car moving before impact) must be either a fully loaded car having a minimum rail load of 160,000 pounds with a standard-travel draft gear, of the car containing the cargo being studied, whichever has the greater weight

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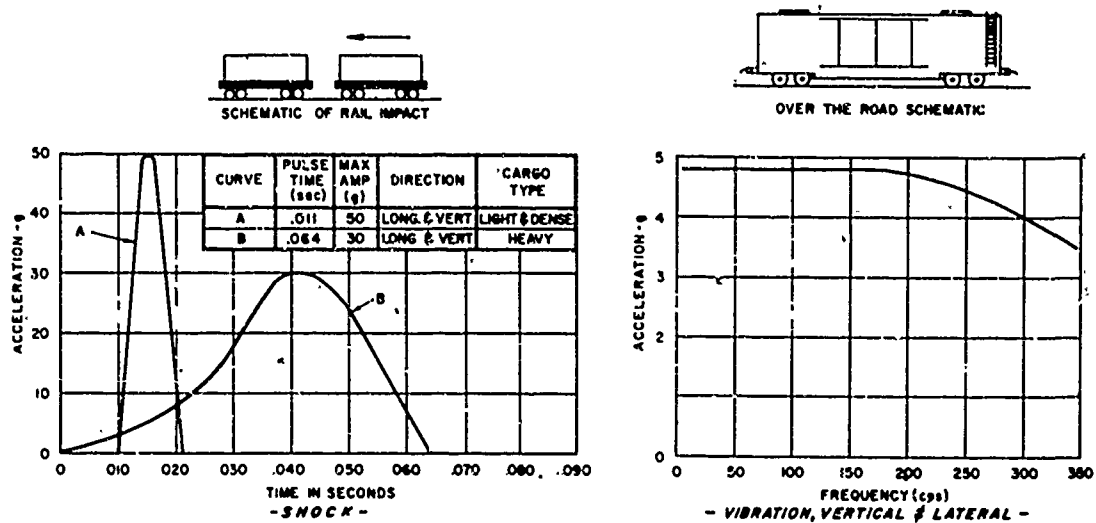
Figure 11. Technical Bulletin.

14

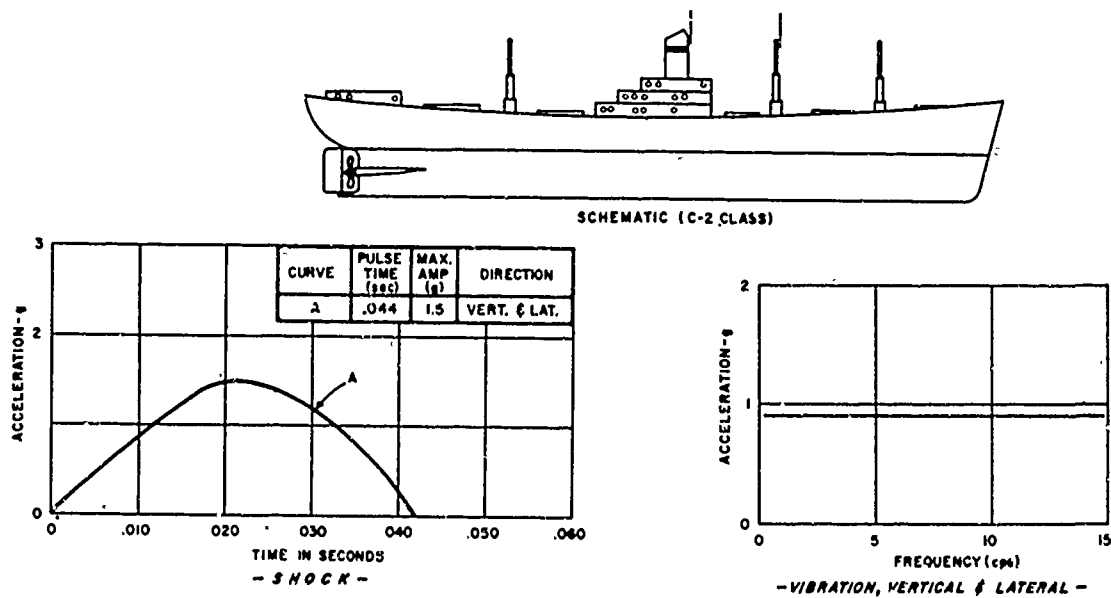Figure 12. Cargo Environments for Rail Transport.

Figure 13. Cargo Environments for Sea Transport.

Preferred criteria input would be statistical data taken from a great number of actual movements. What most have to settle for are simulated set-ups with unsubstantiated inputs. For the TB, most of the data were based on simulated transportation loadings. Some of the sea criteria were taken entirely from actual shipments. Considerable work is now in process to strengthen the amount of criteria gained from actual movements. It is
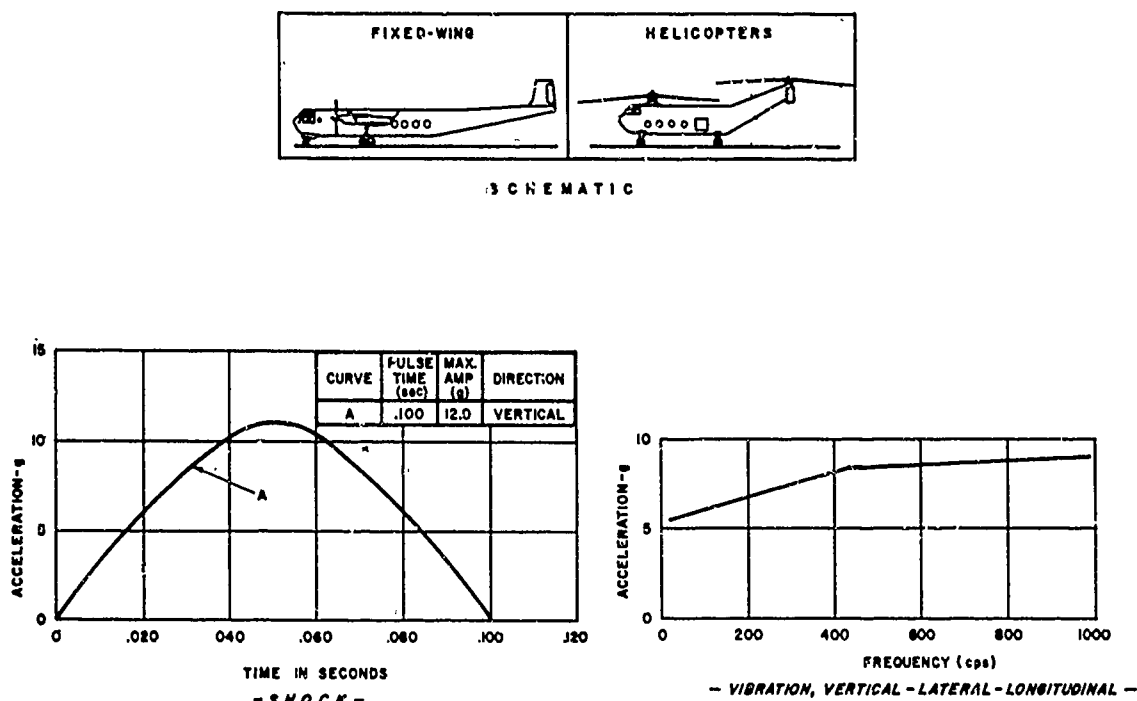
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Figure 14.   Cargo Environments for Air Transport.

anticipated that in the near future factors limiting the amount of data
collectable from actual movements will be solved and a great majority of
the criteria will be based on actual happenings.

Transportation criteria are now being formed, and efforts and interest
in this area are increasing.   Transportation Corps efforts in this area will
continue.   Programs call for more study, more analysis, and more in-
strumented movements.   An expansion in the program to get a more com-
plete input from the military, from research institutions, and from in-
dustry is planned.   Many of the programs that are now scheduled will be
reviewed for potential transportation criteria.   The Chief of Transporta-
tion plans to expand TB 55-100 and to ensure that the Department of Army
position reflects the latest criteria on a continuing basis.

The response in the first few months after publication of the TB has been
excellent.   Although distribution was broad, several requests for the TB
are received daily.   Certainly not all are in agreement with every aspect
of the criteria, but all are in agreement that this type of document is
urgently needed.   Many agencies have expressed an interest and a desire
to contribute input to the criteria program.   This action is encouraged.
Greater cooperation among all agencies (Government, commercial, and
research) will result in efficient, effective, and timely criteria.
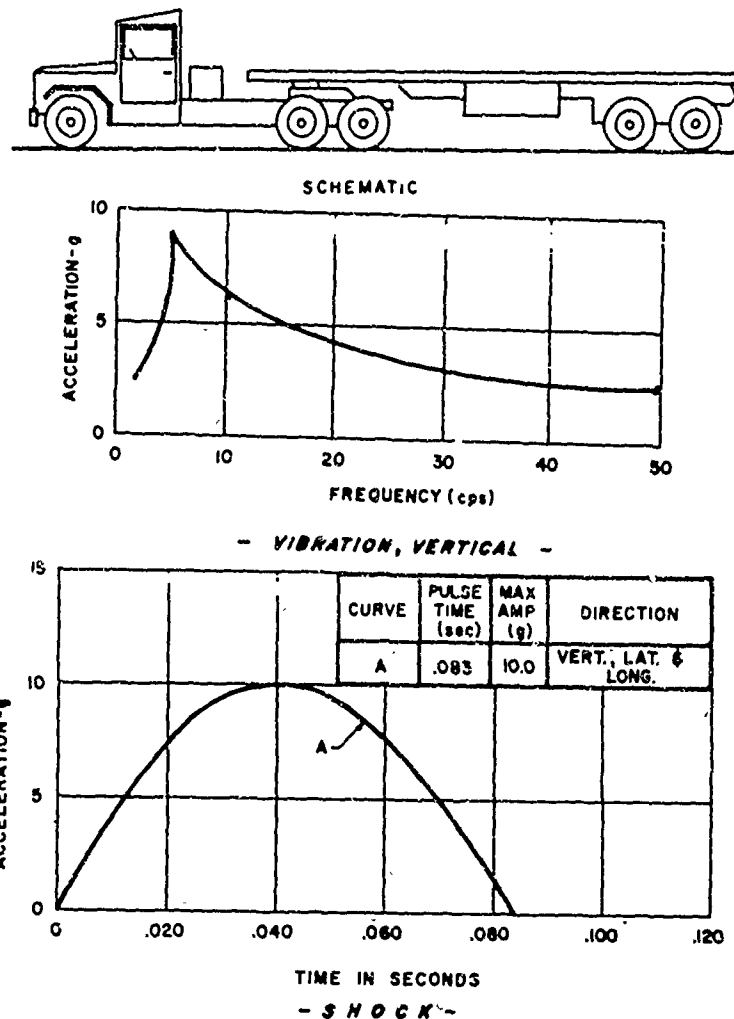
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SCHEMATIC

— VIBRATION, VERTICAL —

CURVE	PULSE TIME (sec)	MAX AMP (g)	DIRECTION
A	.083	10.0	VERT., LAT. & LONG.

TIME IN SECONDS

— SHOCK —

Figure 15. Cargo Environments for Highway Transport.

CONCLUSIONS

The target of this work is to obtain an interchange of transportation-induced shock and vibration environment criteria. Acceptance or rejection of the specific numbers in TB 55-100 is secondary. At this time, criteria communication and criteria application are paramount.

Effecting, publishing, and instituting good shock and vibration criteria can be successful within the framework of the present organizational structure of the field of shock and vibration. Initial work has indicated a continued strengthening of criteria efforts.

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All shock and vibration criteria must be based on technically sound inputs. The great expense and effort required to comply with criteria necessitate a well founded basis.

To be useful, shock and vibration criteria must get to personnel who have a direct need for it. Designers, research and development engineers, and developers all have an accepted need for good criteria. Personnel having the choice of mode of transportation, as well as operating personnel who actually make shipments, appear to have the greatest unfulfilled need at present for criteria in published form.

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